
Sewerable Water

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Introduction

In 1996, the Livermore site discharged approximately 1 million liters (ML) per day of wastewater to the City of Livermore sewer system, an amount that constitutes 4.6% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories/California (SNL/California), which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system. In 1996, SNL/California generated approximately 20% of the total effluent discharged from the Livermore site. LLNL's wastewater contains sanitary sewage and industrial wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below in the Pretreatment and Categorical Discharges section.

The effluent is processed at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management Program, the treated sanitary wastewater is transported out of the valley through a pipeline and discharged into San Francisco Bay. A small portion of this treated wastewater is used for summer irrigation of the adjacent municipal golf course. Sludge from the treatment process is disposed of in sanitary landfills.

LLNL receives water from two suppliers. LLNL's primary water source is the Hetch-Hetchy Aqueduct. Secondary or emergency water deliveries are taken from the Alameda County Flood Control and Water Conservation District Zone 7. This water is a mixture of ground water and water from the South Bay Aqueduct of the State Water Project. Water quality parameters for the two sources are obtained from the suppliers and are used to evaluate compliance with the discharge permit conditions that limit changes in water quality between receipt and discharge.

Preventive Measures

Administrative and engineering controls at the Livermore site are designed to prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Waste generators receive training on proper waste handling. LLNL personnel review facility procedures and inspect processes for inappropriate discharges. Retention



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tanks collect wastewater from processes that might release contaminants in quantities sufficient to disrupt operations at the LWRP. Ground water generated from remediation treatment, hydraulic tests, and volatile organic compound (VOC) treatability studies is analyzed for pollutants of concern and must meet permitted criteria or LWRP approval must be obtained before it can be discharged to the sanitary sewer. Finally, to verify the success of training and control equipment, wastewater is sampled and analyzed not only at the significant points of generation, as defined by type and quantity of contaminant generated, but also at the point of discharge to the municipal sewer system.

To ensure the integrity of the wastewater collection system, LLNL completed an aggressive assessment and rehabilitation program in 1995. Begun in 1992, the program tested all known building drains to determine their points of discharge. Identified deficiencies, considered to be illicit connections, were classified and corrected; major deficiencies were immediately remedied. Finally, preparatory to relining with a synthetic sock, the major laterals of the sanitary sewer system were videotaped and evaluated. Major line failures were repaired. In addition, retention tanks have undergone comprehensive evaluation and rehabilitation.

For facilities with installed retention tank systems, collected wastewater is discharged to the sanitary sewer only if analytical laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). LLNL developed internal discharge guidelines for specific sources and operations to ensure that sewer effluent for the entire site complies with LLNL's waste discharge permit. If pollutant levels exceed permissible concentrations, the wastewater is treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or it is shipped to an off-site treatment or disposal facility. Liquids containing radioactivity are handled on site and may be treated using processes that reduce the activity to levels well below those required by DOE Order 5400.5. Internal guidelines for retention tank systems and specific sources and operations are discussed below in the "Pretreatment and Categorical Discharges" section.

For the year as a whole, the monitoring data reflect the success of LLNL's discharge control program in preventing any significant impact on the operations of Livermore's treatment plant and are generally consistent with past values.

Continuous Monitoring

LLNL's sanitary sewer discharge permit requires continuous monitoring of the effluent flow rate and pH. Samplers collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, toxic chemicals, and water-quality parameters. In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might upset the LWRP treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for pH, selected metals, and



radioactivity. If concentrations above warning levels are detected, an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control and, since July 1990, automatically notifies the LWRP in the event that contaminants are detected. Trained staff respond to all alarms to evaluate the cause and take appropriate action.

A major upgrade to the continuous monitoring system was completed in the final quarter of 1996. Analyzers for continuous monitoring of metals were redesigned to increase the operational safety of the system and to decrease the length of downtime in the continuous monitoring of metals. The redesign included replacement of x-ray tubes and power supplies used in the analyzers, reconfiguration of x-ray shielding to accommodate the physical characteristics of the new x-ray tubes, and installation of an enclosure that surpasses safety mandates.

Diversion System

In 1991, LLNL completed construction of a diversion system that is automatically activated when the monitoring system sounds an alarm. The diversion system ensures that all but the first few minutes of the affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any required cleanup. Up to 775,000 L of potentially contaminated sewage can be held pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if the liquid is not hazardous or after it is treated, depending on analytical results), shipped for off-site disposal, or treated at LLNL's Hazardous Waste Management Facility. All diverted sewage in 1996 was returned to the sanitary sewer.

Satellite Monitoring

In 1991, LLNL completed the implementation of a system of 10 satellite monitoring stations that operates in conjunction with the sewer monitoring system (**Figure 6-1**). The satellite monitoring stations are positioned at strategic locations within the main sewer system to help pinpoint the on-site area from which a release might have originated. Each station consists of an automatic sampler that collects samples on a time-proportional basis. If there is a release, these samples are analyzed. However, early in 1994, all but two (86B and 51A) of the satellite monitoring stations were taken off line pending ergonomic reengineering of the equipment used during routine maintenance. In 1995, one satellite monitoring station (163A) was restored to operation. In 1996, no changes were made to the satellite monitoring system. This satellite monitoring station is located at the point of discharge of SNL/California wastewater to the LLNL collection system. The low number of unacceptable releases to the sewer (those which might upset the LWRP treatment process or otherwise impact the public welfare) has lowered the priority for reengineering the satellite monitoring stations.

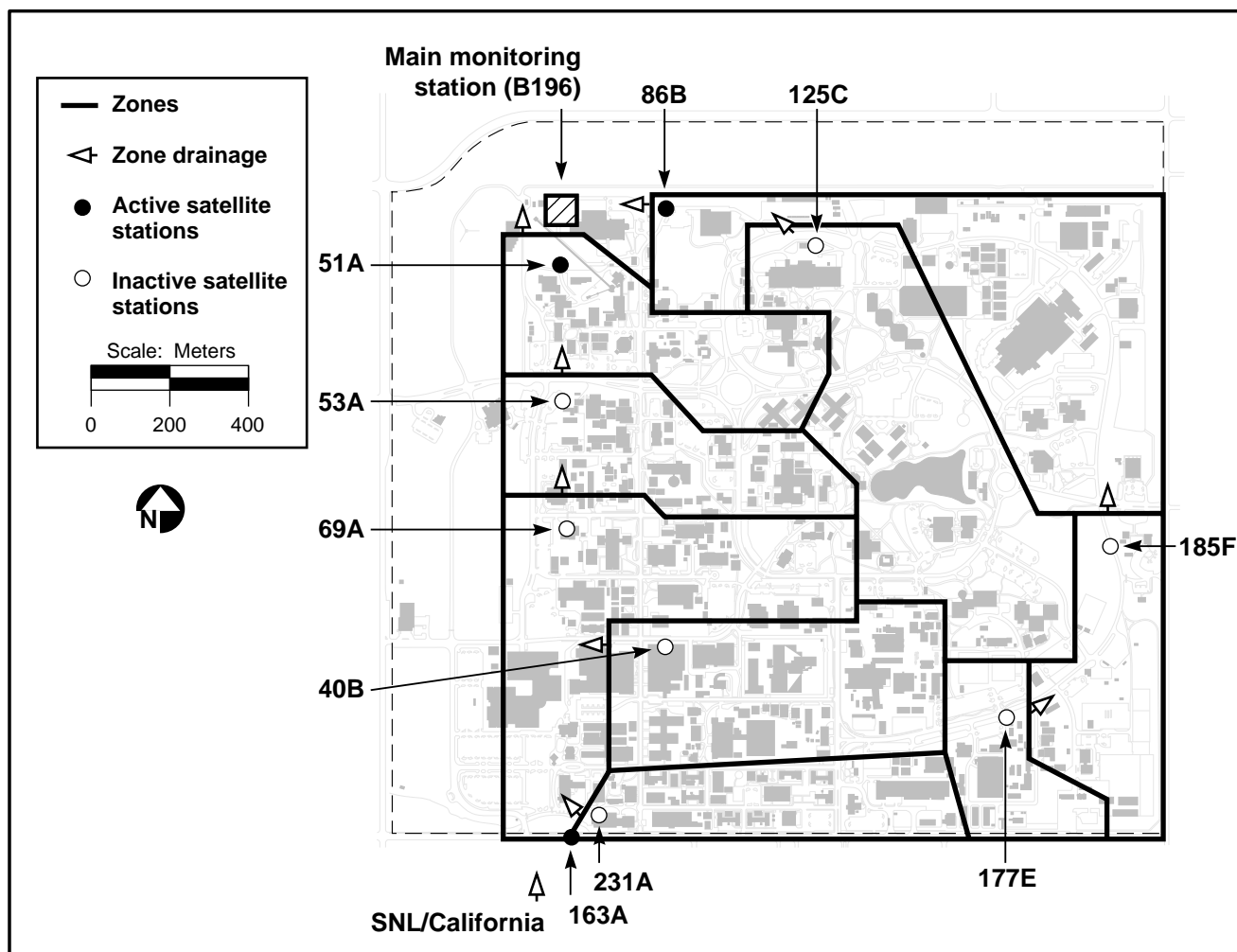


Figure 6-1. Sewer monitoring network.

Pretreatment and Categorical Discharges

Self-monitored pretreatment programs are required at both the Livermore site and Site 300 by the Livermore Water Reclamation Plant (LWRP) under the authority of San Francisco Bay Regional Water Quality Control Board. The sampling and monitoring of nondomestic, industrial sources covered by pretreatment standards defined in 40 CFR 403 is required in the 1996–1997 Wastewater Discharge Permit (No. 1250) issued for the discharge of wastewater from LLNL into the City of Livermore sewer system. Permit 1250 discharge limits are listed in **Table 6-1**. These limits are applied at the site boundary before wastewater enters the LWRP collection system. The General Pretreatment Regulations establish both general and specific standards for the discharge of prohibited substances (40 CFR 403.5) that apply to all industrial users. Categorical



standards are published by the Environmental Protection Agency (EPA) as separate regulations and contain numerical limits for the discharge of pollutants from specified processes (or industrial categories). The LWRP has identified specific LLNL wastewater generating processes that fall under the definition of two Categorical Standards: electrical and electronic components (40 CFR 469), and metal finishing (40 CFR 433).

Table 6-1. Limits under permit 1250 for discharges into the municipal sewer.

Constituent	Discharge limit
Metals (mg/L)	
Arsenic	0.06
Cadmium	0.14
Copper	1.0
Chromium (total)	0.62
Lead	0.20
Mercury	0.01
Nickel	0.61
Silver	0.20
Zinc	3.0
Cyanide (mg/L)	0.04
Toxic organics (total)	1.0
pH	5–10

Previously, LLNL petitioned the EPA for an exemption from these two Categorical Standards, and formal monitoring and reporting requirements for these regulated processes were subsequently suspended. Quarterly and semiannual sampling of minor discharges was suspended and semiannual wastewater reports were not submitted to the LWRP, and the LWRP suspended its inspection schedule of the regulated processes at LLNL. This was done with the concurrence of both the LWRP and the Pretreatment Coordinator, EPA Region 9. During 1996, LLNL maintained compliance with categorical standard discharge limits for significant industrial processes that discharge to the sanitary sewer by reviewing retention-tank data prior to discharge and applying the appropriate categorical discharge limits. The analytical data and discharge records are available for review by regulatory agencies. In December 1996, LLNL was notified of EPA's decision regarding the request for exemption in a report of their 1995 Clean Water Act (CWA)/NPDES inspection of LLNL's Livermore site. The EPA report stated that although they do exempt research laboratories from regulation under the categorical standards, they do not exempt operations in support of research, such as parts fabrication or waste handling. Therefore, LLNL resumed self-monitoring of its federally regulated discharges in 1997 as prescribed in the Wastewater Discharge Permit (No. 1250).



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Tables 6-2 and 6-3 show LLNL's internal discharge limits for wastewaters discharged to the sanitary sewer. Those processes that discharge to the sanitary sewer are subject to the pretreatment self-monitoring program specified in the Ground Water Discharge Permit issued by the LWRP. In 1996, nine exceptions to the pollutant limitations of the discharge permit were observed and are discussed below in the "Environmental Impact of Nonradioactive Liquid Effluents" section.

Table 6-2. Discharge limits for nonradioactive pollutants in wastewaters at point of discharge into LLNL sewer.

Parameter	Discharge limits				
	Internal ^(a)	Metal finishing ^(b)	Electric components ^(b)	Permit 1508	Permit 1510
Metals (mg/L)					
Arsenic	NA ^(c)	NA	0.83	0.06	0.06
Beryllium	0.74	— ^(d)	— ^(d)	— ^(d)	— ^(d)
Cadmium	0.9	0.26	— ^(d)	0.14	0.14
Chromium (total)	4.9	1.71	— ^(d)	0.62	0.62
Copper	1.0	2.07	— ^(d)	1.00	1.00
Lead	4.9	0.43	— ^(d)	0.20	0.20
Mercury	0.05	— ^(d)	— ^(d)	0.01	0.01
Nickel	5	2.38	— ^(d)	0.61	0.61
Silver	1	0.24	— ^(d)	0.20	0.20
Zinc	15	1.48	— ^(d)	3.00	3.00
Organics (mg/L)					
TTO ^(e)	4.57	2.13	1.37	1.00	1.00
BTEX ^(f)	NA	NA	NA	0.25	NA
Other (mg/L)					
Cyanide ^(g)	5	0.65	— ^(d)	0.04	0.04
pH	5-10	5-10	5-10	6-9	5-10

^a These standards were established to meet the City of Livermore's requirements at the point of discharge to the Municipal Sewer (Building 196).

^b These standards were specified by EPA. By regulation, the EPA or City of Livermore limit is used, whichever is lower. Internal limits apply where no standard is specified.

^c NA = Not applicable.

^d Noncategorical limits apply.

^e Total toxic organics.

^f Benzene, toluene, ethyl benzene, and xylene.

^g Limits apply to cyanide discharges other than cyanide salts. CN salts are classified by the State of California as "extremely hazardous waste" and cannot be discharged to the sewer.



Table 6-3. LLNL's internal discharge limits for radioisotopes in wastewaters. There is no gross gamma limit; isotope-specific limits apply.

Parameter	Individual discharges	Total daily limit for site
Gross alpha	11.1 Bq/L (0.3 μ Ci/1000 L)	185 kBq (5.0 μ Ci)
Gross beta	111 Bq/L (3.0 μ Ci/1000 L)	1.85 MBq (50.0 μ Ci)
Tritium	185 kBq/L (5.0 mCi/1000 L)	3.7 GBq (100.0 mCi)

LLNL's ground water discharge permit (1510G, 1996–1997) allows ground water from hydraulic tests and VOC treatability studies to be discharged to the City of Livermore sanitary sewer in compliance with **Table 6-1** effluent limitations taken from the Livermore municipal code. During 1996, over 1 ML of ground water from sitewide CERCLA cleanup activities was discharged to the sanitary sewer. Discharges were primarily from start-up operations associated with portable treatment unit construction and testing. Twenty-one separate discharges were sampled and discharged to the sewer during this period, all in compliance with the metals, total toxic organic, and self-monitoring permit provisions of self-monitoring permit 1510G. Concentrations of constituents of concern were all below discharge limits. Detections of regulated substances are summarized in **Table 6-4**. Complete monitoring data are in Volume 2.

Radioactive Pollutants in Sewage

Monitoring Results

Determination of the total radioactivity released from tritium, alpha emitters, and beta emitters is based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever is higher (see **Table 6-5**). The 1996 combined releases of tritium and alpha and beta sources were 12.3 GBq (0.33 Ci). The total is based on the results shown in **Table 6-5**; unlike previous years, the 1996 total does not include a contribution from SNL/California. SNL/California concluded all of its tritium research activities as of October 1994, and the cleanup activities at their former tritium research laboratories were completed by October 1995. The annual mean concentration of tritium in LLNL sanitary sewer effluent was 0.035 Bq/mL (0.95 pCi/mL).



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Table 6-4. Compounds detected in water discharged to the sanitary sewer in 1996 under permits 1508 and 1510.

Parameter	Discharge date					
	3/22	4/11–12	4/23	4/25	6/4–12	6/6
Metals (mg/L)						
Arsenic	—(a)	—(a)	—(a)	—(a)	—(a)	0.0032
Chromium (total)	0.005	0.005	0.009	0.008	0.0071	0.029
Chromium(VI)	—(a)	—(a)	0.013	0.006	—(a)	—(b)
Copper	0.002	—(a)	0.008	0.011	—(a)	0.023
Lead	—(a)	—(a)	—(a)	—(a)	0.0029	0.0065
Mercury	—(a)	—(a)	—(a)	0.0007	—(a)	—(a)
Nickel	—(a)	0.002	—(a)	—(a)	—(a)	0.031
Zinc	—(a)	—(a)	—(a)	—(a)	—(a)	0.022

Table 6-4. Compounds detected in water discharged to the sanitary sewer in 1996 under permits 1508 and 1510 (concluded).

Parameter	Discharge date						
	6/23	6/25–28	6/27	7/10	9/10–27	10/8–11	10/15–18
Metals (mg/L)							
Arsenic	—(b)	—(a)	—(a)	—(a)	—(a)	—(a)	—(a)
Chromium (total)	—(b)	0.014	0.010	0.028	0.040	0.008	0.010
Chromium(VI)	—(b)	0.014	—(a)	—(a)	0.025	0.010	0.015
Copper	—(b)	—(a)	—(a)	0.015	0.023	—(a)	—(a)
Lead	—(b)	—(a)	—(a)	0.0058	0.031	—(a)	—(a)
Mercury	—(b)	—(a)	—(a)	0.0068	—(a)	0.00021	—(a)
Nickel	—(b)	—(a)	—(a)	0.020	0.003	—(a)	—(a)
Zinc	—(b)	—(a)	—(a)	—(a)	0.04	—(a)	—(a)
Organics (µg/L)							
TTO ^(c)	—(a)	—(a)	2.4	—(a)	—(a)	—(a)	—(a)
BTEX	11.7	—(a)	—(a)	—(a)	—(a)	—(a)	—(a)

^a Not detected.

^b Not analyzed

^c Trichloroethylene

^d Benzene, toluene, ethyl benzene, and xylene.

**Table 6-5.** Estimated total radioactivity in LLNL sanitary sewer effluent, 1996.

Radioactive emitter	Estimate based on effluent activity (GBq) ^(a)	Limit of sensitivity (GBq)
Tritium	12.0	3.7
Alpha sources	0.064	0.063
Beta sources	0.24	0.057

^a 37 GBq = 37×10^9 Bq = 1 Ci.

The concentrations of ^{239}Pu , ^{137}Cs , and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 6-6**. The tritium numbers are based on the flow-weighted average of the individual daily sample results for a given month. The plutonium and cesium numbers are the direct result of analysis of monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. At the bottom of the table, the total activity released is given by radioisotope. This was calculated by multiplying each sample result by the total flow volume over which the sample was collected, and summing up over all samples. The total activity released for each radioisotope is a conservative value; the limit of sensitivity was used in the calculation when the limit of sensitivity was greater than the actual activity reported. Also included in the table are fractions of DOE and 10 CFR 20 limits, discussed in the Environmental Impact section of this chapter.

The historical trend in the monthly average concentration of tritium is shown in **Figure 6-2**. Also included in the figure is the DOE tritium limit (370 Bq/mL), discussed in the Environmental Impact section of this chapter. The trend plot in **Figure 6-2** indicates a well-controlled tritium discharge, which is orders of magnitude below the DOE tritium limit.

Figure 6-3 shows the average monthly plutonium and cesium concentrations in sewage since 1985. The annual mean concentration of ^{137}Cs was 12 $\mu\text{Bq/mL}$ (3.2×10^{-4} pCi/mL); the annual mean ^{239}Pu concentration was 1.2 $\mu\text{Bq/mL}$ (3.2×10^{-5} pCi/mL).

Environmental Impact of Radioactive Pollutants in Sewage

During 1996, no inadvertent releases exceeded any discharge limits for release of radioactive materials to the sanitary sewer system.



Table 6-6. Various radionuclides in sanitary sewer effluents, LLNL and Livermore Water Reclamation Plant (LWRP), 1996.

Month	³ H (mBq/mL) ^(a)		¹³⁷ Cs (μBq/mL)		²³⁹ Pu (nBq/mL)		²³⁹ Pu (mBq/dry g)
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge ^(b)
Jan	3.5	−0.16	0.88 ± 0.37	<0.41	112 ± 43	9.0 ± 16.7	0.43 ± 0.05
Feb	4.2	0.48	1.1 ± 0.3	<0.54	414 ± 74	2.6 ± 12.5	
Mar	8.4	0.36	88 ± 2	2.2 ± 0.4	2710 ± 186	20.2 ± 13.7	
Apr	30 ± 11	0.43	18 ± 1	1.3 ± 0.5	2610 ± 208	13.6 ± 13.3	
May	20 ± 11	−0.16	5.6 ± 0.7	0.67 ± 0.41	1170 ± 135	20.0 ± 14.4	1.6 ± 0.1
Jun	3.2	1.7	7.3 ± 0.7	<0.56	1300 ± 178	10.8 ± 15.0	
Jul	13 ± 10	10	2.4 ± 0.7	<0.56	777 ± 146	10.4 ± 11.4	
Aug	36 ± 10	4.2	6.6 ± 0.6	<0.44	673 ± 118	−2.61 ± 6.66	
Sep	36 ± 10	1.5	5.8 ± 0.7	<0.94	3770 ± 342	20.9 ± 13.9	4.1 ± 0.4
Oct	22 ± 9	1.7	1.8 ± 0.5	<0.57	518 ± 81	−2.94 ± 6.36	0.52 ± 0.07
Nov	107 ± 10	3.0 ± 10.0	1.60 ± 0.03	<0.37	280 ± 53	6.9 ± 12.4	
Dec	84 ± 11	1.4 ± 10.6	5.7 ± 0.5	<0.63	681 ± 93	−2.19 ± 8.18	
Median	21	<1.2	5.6	0.56	729	9.7	
IQR ^(c)	29	— ^(d)	5.0	— ^(d)	1140	13.8	1.7
	pCi/mL ^(e)						pCi/ dry g ^(e)
Median	0.57	<0.032	1.5 × 10 ^{−4}	1.5 × 10 ^{−5}	2.0 × 10 ^{−5}	2.6 × 10 ^{−7}	0.028
IQR	0.78	— ^(d)	1.4 × 10 ^{−4}	— ^(d)	3.1 × 10 ^{−5}	3.7 × 10 ^{−7}	0.046
	Annual total discharges by radioisotope						
	³ H ^(f)		¹³⁷ Cs		²³⁹ Pu		Total ^(f)
Bq/y	1.2 × 10 ¹⁰		4.2× 10 ⁶		4.2× 10 ⁵		1.2× 10 ¹⁰
Ci/y	0.32		1.1 × 10 ^{−4}		1.1 × 10 ^{−5}		0.32
	Fraction of limit						
DOE	9.4 × 10 ^{−5}		2.2 × 10 ^{−5}		3.3 × 10 ^{−6}		9.4 × 10 ^{−5}
10 CFR 20	0.065		3.3 × 10 ^{−5}		1.7 × 10 ^{−4}		— ^(g)

Note: Radionuclide results are reported $\pm 2\sigma$; see Chapter 13, Quality Assurance.

^a Ranges are only listed for activities that are above the limit of sensitivity.

^b Sludge from LWRP digesters is dried before analysis. The resulting data indicate the plutonium concentration of the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

^c Interquartile range.

^d Because of the large number of nondetections, the interquartile range is omitted. See Chapter 13, Quality Assurance.

^e 1 Ci = 3.7×10^{10} Bq.

^f Does not include gross alpha and beta results shown in Table 6-5.

^g The fraction of the 10 CFR 20 limit is not presented because tritium discharges have an annual limit and cesium and plutonium discharges have monthly concentration-based limits. See the individual fractions for each of these radioisotopes.

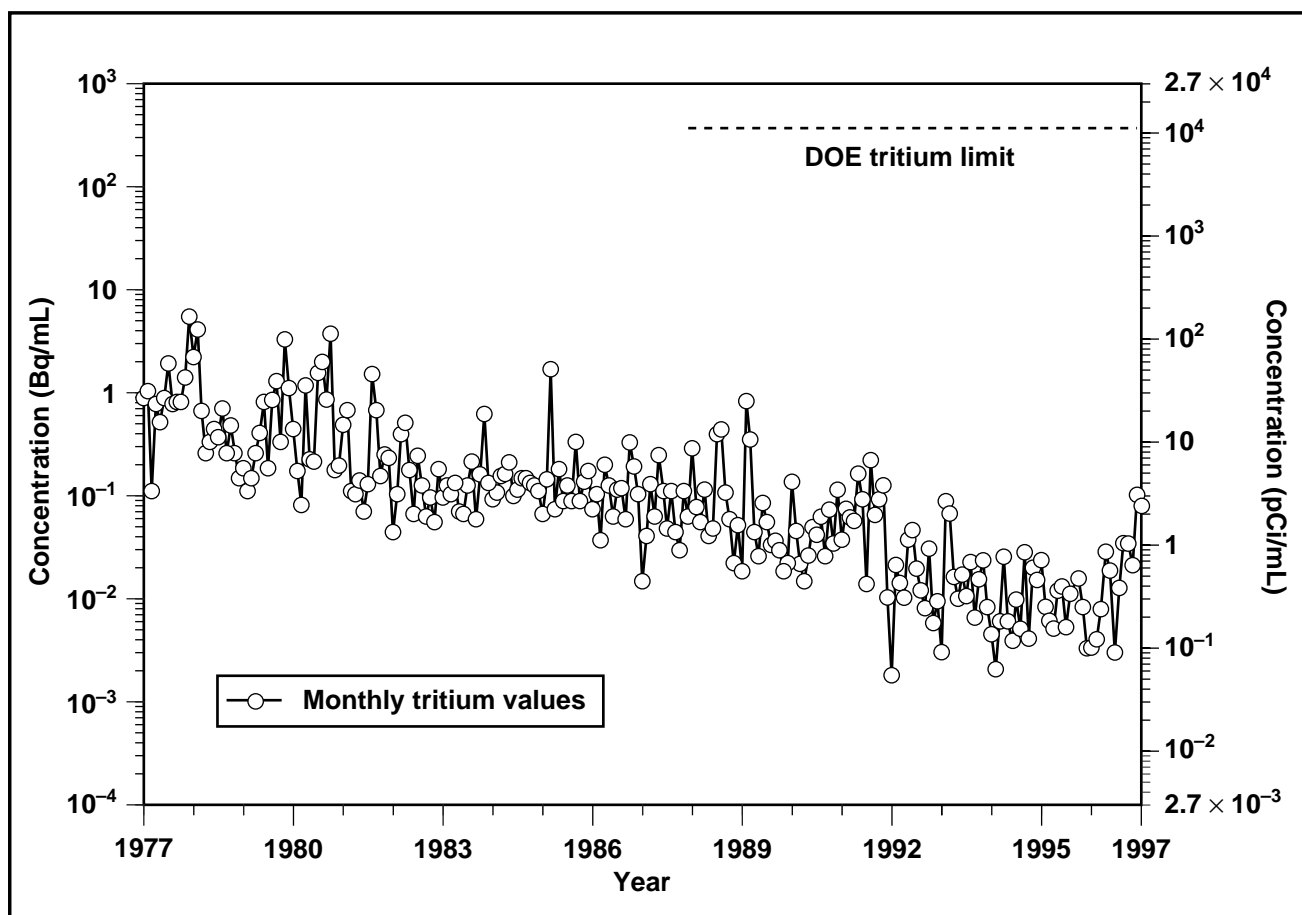


Figure 6-2. Historical trend in tritium concentration in LLNL sewage.

DOE Order 5400.5 established DOE policy requiring that radiological releases to the sanitary sewer comply with legally applicable local and state regulations and that LLNL implement standards generally consistent with those of the Nuclear Regulatory Commission. The most stringent of these limits was adopted in Title 17 of the California Code of Regulations. As a federal facility, LLNL is formally exempt from the requirements of state regulations but follows those requirements under the guidance of DOE. Title 17 contained a limit on discharges of radioactivity in sewage of 37 GBq (1 Ci) each year; it also listed limits on the daily, monthly, and annual concentration for each specific radionuclide.

In 1994, the discharge requirements previously found in Title 17 were removed and the requirements in Title 10 of the Code of Federal Regulations, Part 20, incorporated by reference. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci); in addition, it specifies that the discharge material must be soluble and lists limits on monthly concentrations.



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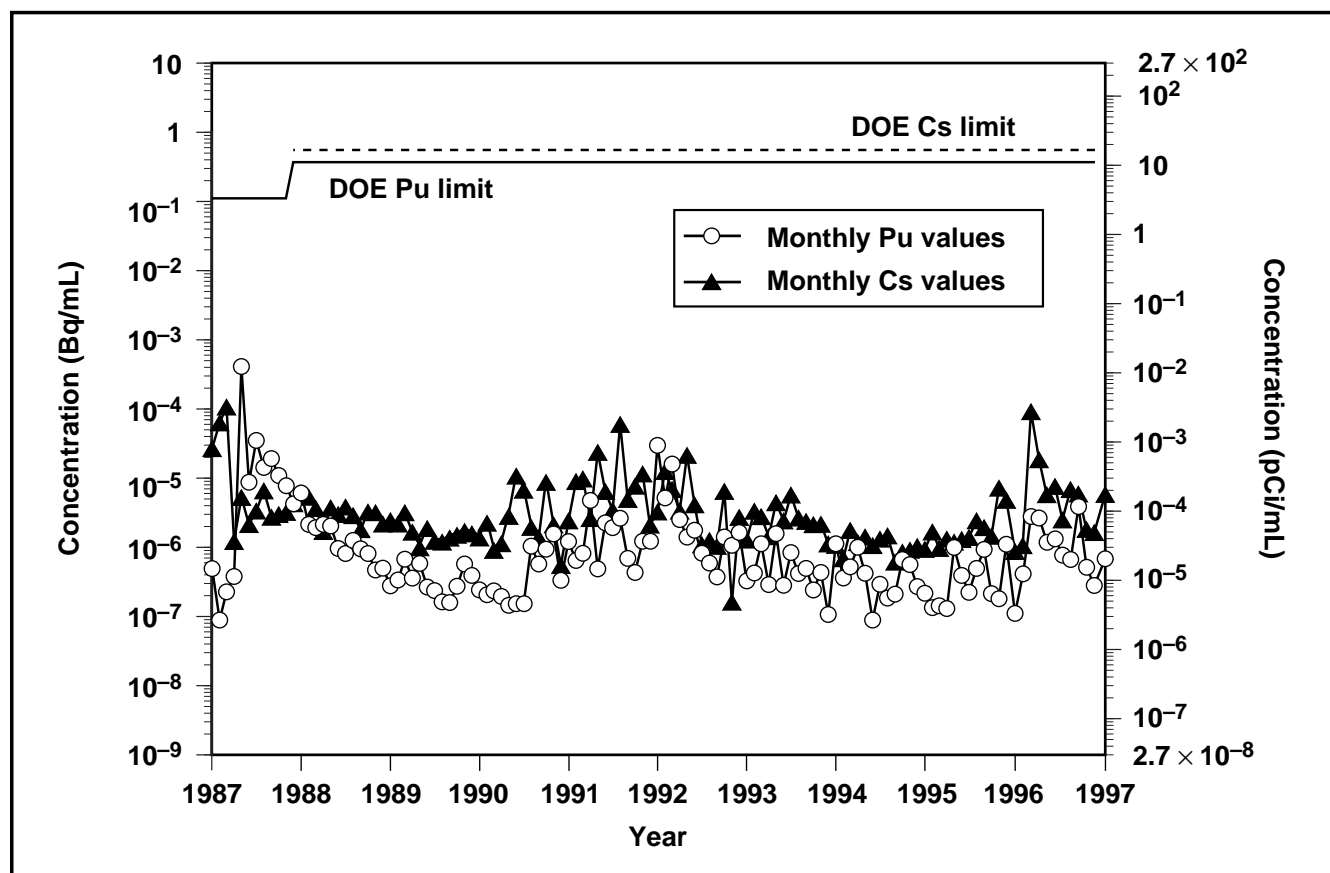


Figure 6-3. Historical trends in plutonium and cesium concentration in LLNL sewage.

Table 6-7 summarizes the discharge requirements of Title 10. Because Title 10 permits and therefore applies to only soluble discharges, and because the plutonium in LLNL effluent is in both the soluble and insoluble forms, the discharge requirement for ^{239}Pu is not directly applicable. This assumption is supported by our experience during the sewer system evaluation, when increased cleaning led to higher plutonium concentrations in LLNL sewage (Gallegos et al. 1992). This indicates that a portion of the soluble plutonium discharges from LLNL facilities is deposited on the sewer pipes, and when these deposits are liberated and discharged from the LLNL site, they are, by their nature, insoluble.

Table 6-7 also includes the total activity that could have been discharged by LLNL during a given period (monthly and annually) using 10 CFR 20 monthly concentrations in conjunction with the annual caps and assuming the 1996 average monthly flow rate. As the table shows, the Title 10 concentration limits for tritium for facilities such as LLNL that generate wastewater in large volumes are overridden by the limit on total tritium activity (18.5 GBq) dischargeable during a single year. In 1996, the total LLNL tritium release was 6.5% of the corresponding Title 10 limit. Total LLNL releases



(Table 6-5), in the form of alpha and beta emitters (excluding tritium), were 0.82% of the corresponding Title 10 limit.

Table 6-7. Sewer discharge release limits for ^3H , ^{137}Cs , and ^{239}Pu .

	^3H	^{137}Cs	^{239}Pu
10 CFR 20 concentrations used to establish release limits (Bq/mL)	370	0.37	0.0074
10 CFR 20 (GBq)			
Monthly	185 ^(a)	11	0.21
Yearly	185 ^(a)	37 ^(b)	2.6
DOE annualized discharge limit for application of BAT ^(c) (Bq/mL)	370	0.56	0.37

^a 10 CFR 20 imposes a 185-GBq (5-Ci) limit for the tritium radiation released.

^b 10 CFR 20 imposes a 37-GBq (1-Ci) combined limit on the total of all radiation released (excluding tritium and C^{14} , which have separate 10 CFR 20 limits of 185 GBq and 37 GBq, respectively); i.e., the total release of all isotopes must not exceed 37 GBq. If a total of 37 GBq of a particular isotope were released during the year, this would require that no other isotopes be released.

^c The DOE annualized discharge limit for application of best available technology (BAT) is five times the Derived Concentration Guide (DCG; ingested water) for each radionuclide released.

DOE has also established criteria for the application of best available technology to protect public health adequately and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each specific radionuclide discharged to publicly owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeded its concentration limit, LLNL would be required to improve discharge control measures until concentrations were again below the DOE limits. Table 6-7 presents the DCGs for the specific radioisotopes of most interest at LLNL.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 9.4×10^{-5} (that is, 0.0094%) of the DOE DCG (and the Title 10 limit); the annual average concentration of ^{137}Cs was 2.2×10^{-5} (0.0022%) of the DOE DCG (and 3.3×10^{-5} or 0.0033% of the Title 10 limit); and the annual average ^{239}Pu concentration was 3.3×10^{-6} (0.00033%) of the insoluble ^{239}Pu DOE DCG, 2.3×10^{-4} (0.023%) of the soluble ^{239}Pu DOE DCG, and 1.7×10^{-4} (0.017%) of the Title 10 limit. The combined discharges were therefore within the range from 1.2×10^{-4} (0.012%) to 3.5×10^{-4} (0.035%) of the DCG, corresponding to calculations incorporating an exclusively insoluble and soluble ^{239}Pu contribution, respectively. As discussed earlier in this section, the plutonium in LLNL effluent is assumed to be present both in the soluble and insoluble forms.



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LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 6-8** summarizes the radioactivity in liquid effluent released over the past 10 years. During 1996, a total of 12.0 GBq (0.32 Ci) of tritium was discharged to the sanitary sewer. As indicated earlier in this chapter, this release does not include a contribution from SNL/California; LLNL therefore discharged 12.0 GBq (0.32 Ci), an amount that is well within environmental protection standards and is comparable to the amounts reported for the last several years. Moreover, the total tritium released by LLNL in 1996 (and the years from 1992 through 1995) is below the range reported prior to 1992.

Table 6-8. Radioactive liquid effluent releases from the Livermore site, 1987–1996.

Year	Liquid effluents (GBq)	
	^3H	^{239}Pu
1987	52	2.6×10^{-2}
1988	56	8.1×10^{-4}
1989	59	1.8×10^{-4}
1990 ^(a)	25	2.3×10^{-4}
1991	32	6.1×10^{-4}
1992	8	1.9×10^{-3}
1993	13	2.6×10^{-4}
1994 ^(b)	6.9	1.9×10^{-4}
1995	6.0	1.2×10^{-4}
1996 ^(c)	12	4.2×10^{-4}

^a The 1990 DOE Order 5400.5 required compliance with legally applicable local and state regulations such as California Title 17, which mandated a 37 GBq (1 Ci) combined limit on the total of all radiation released.

^b In 1994, the discharge requirements previously found in Title 17 were changed to correspond to the requirements in Title 10 of the Code of Federal Regulations, Part 20. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci).

^c The 1996 total for tritium does not include a contribution from SNL/California; in 1995, SNL/California ceased all tritium facility operations.

Figure 6-3 summarizes the ^{239}Pu monitoring data over the past 10 years. The historical levels observed since 1987 average $2 \mu\text{Bq/mL}$ ($5 \times 10^{-5} \text{ pCi/mL}$), with the exception of a peak in 1987. Even this peak is well below the DOE DCG's for both the soluble and insoluble forms of ^{239}Pu . Historically, levels generally are four-thousandths (0.004) and six-millionths (0.000006) of these soluble and insoluble limits, respectively. The greatest part of the plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge, which is dried and disposed of at a landfill. The plutonium concentration observed in 1996 sludge (**Table 6-6**), 1.0 mBq/dry g (0.027 pCi/dry g),



is more than 400 times lower than the proposed EPA guideline for unrestricted use of soil (480 mBq/dry g).

As first discussed in the Environmental Report for 1991 (Gallegos et al. 1992), plutonium and cesium concentrations were slightly elevated during 1991 and 1992 over the lowest values seen historically. As was established in 1991, the overall upward trend was related to sewer cleaning with new, more-effective equipment. During 1993, as utility personnel worked to complete an assessment of the condition of the sewer system, cleaning activity around the site was less extensive, resulting in slightly lower plutonium and cesium concentrations in LLNL effluent. During 1994, in conjunction with the installation of the synthetic sock lining in the sewer system, the cleaning activity around the site was more extensive than in 1993. However, by the end of 1993 the new sewer cleaning equipment had been used on LLNL's entire sewer system; this was reflected in 1994 and the majority of 1995 by the continuation of the slightly lower plutonium and cesium concentrations that were observed in the 1993 effluent.

The 1996 plutonium and cesium concentrations are slightly higher than the concentrations observed over the past several years (1993 through 1995), and slightly lower than the observed concentrations of 1990 through 1992, with the exception of a cesium peak early in 1996. This peak, pictured in **Figure 6-3** and reported in **Table 6-6**, is attributable to a controlled release from the LLNL retention tank system and is well below the applicable DOE DCG. The slightly higher plutonium and cesium concentrations of 1996 are well below applicable DOE DCG's and remain indicative of well-controlled discharges.

Nonradioactive Pollutants in Sewage

Monitoring Results

Table 6-9 presents monthly average metal concentrations in LLNL's sanitary sewer effluent. The averages were obtained by a flow-proportional weighting of the results from analysis of the weekly composite samples and the 24-hour composites collected each month. Each result was weighted by the total flow volume for the period during which the sample was collected. The results are quite typical of the values seen during the previous years, 1994 and 1995 (see **Figure 6-4**), with the exceptions of arsenic and mercury. The arsenic and mercury results are discussed below. **Figure 6-5** compares daily and weekly concentrations of metals in LLNL sewage.

**Table 6-9.** Monthly results for metals in LLNL sanitary sewer effluent (in mg/L), 1996 summary.

Month	Ag	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
Jan	0.014	0.79	0.0032	<0.00050	<0.0050	0.020	0.13	1.7	0.00035	0.0083	0.017	0.26
Feb	0.014	0.46	<0.0020	0.00053	<0.0050	0.011	0.12	1.1	0.00022	0.0073	0.017	0.17
Mar	<0.0082	0.70	0.0021	<0.00050	<0.0041	0.014	0.090	1.5	0.00036	0.0054	0.012	0.20
Apr	0.012	0.65	0.0021	<0.00050	<0.0050	0.013	0.080	1.5	0.00037	0.0066	0.010	0.18
May	0.011	0.92	0.0024	<0.00050	<0.0050	0.017	0.15	1.8	0.00045	0.0085	0.032	0.28
Jun	<0.010	0.48	0.0025	<0.00050	<0.0050	0.011	0.093	1.0	0.00022	0.0051	0.028	0.19
Jul	0.011	0.45	0.0024	<0.00050	<0.0050	0.013	0.12	1.0	0.00024	0.0060	0.017	0.19
Aug	0.010	0.64	0.0024	<0.00050	<0.0050	0.019	0.14	1.3	0.0012	0.0051	0.038	0.23
Sep	0.011	0.59	<0.0020	<0.00050	0.0051	0.018	0.12	1.5	0.0020	0.0053	0.037	0.25
Oct	<0.010	0.39	<0.0020	<0.00050	<0.0050	0.011	0.091	0.92	0.00048	0.0051	0.023	0.17
Nov	0.010	0.61	0.0025	<0.00050	<0.0050	0.016	0.11	1.3	0.0019	0.0059	0.018	0.19
Dec	<0.010	0.44	0.0027	<0.00050	<0.0050	0.014	0.056	1.0	0.00086	0.0051	0.011	0.19
Median	0.011	0.60	0.0024	<0.00050	<0.0050	0.014	0.11	1.3	0.00041	0.0056	0.018	0.19
IQR^(a)	0.001	0.21	0.0004	— ^(b)	— ^(b)	0.005	0.03	0.5	0.00062	0.0016	0.014	0.05
EPL^(c)	0.2	— ^(d)	0.06	— ^(d)	0.14	0.62	1.0	— ^(d)	0.01	0.61	0.2	3.0
Fraction of EPL	0.05	— ^(d)	0.04	— ^(d)	<0.04	0.02	0.11	— ^(d)	0.04	0.01	0.09	0.06

Note: Monthly values are presented with less than signs when all weekly and 24-hour composite sample results for the month are below the detectable concentration.

^a Interquartile range.

^b Because of the large number of nondetects, the interquartile range could not be calculated for these metals. See Chapter 13, Quality Assurance.

^c Effluent pollutant level (LLNL Wastewater Discharge Permit 1995–96 and 1996–97).

^d No established limit for metal.

Detections of anions, metals, and organic compounds and data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 6-10**. Although the samples were analyzed for bromide, nitrite (as N), carbonate alkalinity (as CaCO₃), hydroxide alkalinity (as CaCO₃), the full suite of polychlorinated biphenyls, the full suite of organochlorine pesticides, and cyanide, those analytes were not detected in any sample acquired during 1996, and so are not presented in the table. The results are quite typical of those seen in previous years.

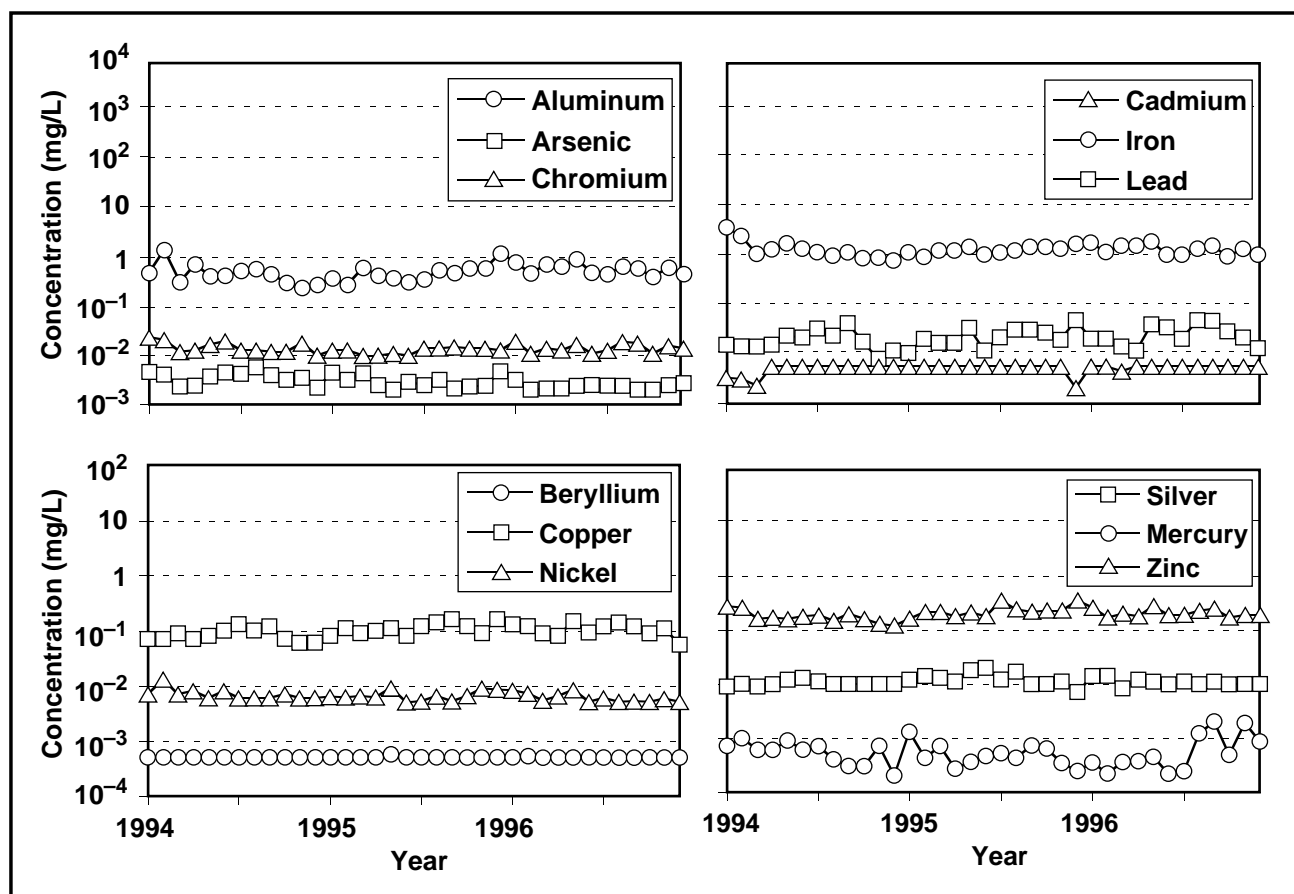


Figure 6-4. Average monthly concentrations of 12 metals in LLNL sanitary sewer effluent showing trends between 1994 and 1996. (Metals are plotted in groups of three for the sake of legibility only.)

Environmental Impact of Nonradioactive Liquid Effluents

In 1996, no inadvertent releases of metals warranted a sewer diversion. At the bottom of **Table 6-9**, the annual median concentration for each metal detected in LLNL's sanitary sewer effluent is compared to the discharge limit. The metals that approached closest to the discharge limits were copper and lead at 11% and 9%, respectively.

Although well below discharge limits, slightly elevated arsenic levels were seen in 1992 through 1995. These levels did not continue in 1996. First discussed in the *Environmental Report 1993* (Gallegos et al. 1994), the elevated arsenic levels were the subject of an extended investigation during 1993, which concluded that the presence of arsenic in the sewer was associated with the ground water cleanup at the gas pad along the southern border of the site. The gas pad cleanup operation was continued in 1994,



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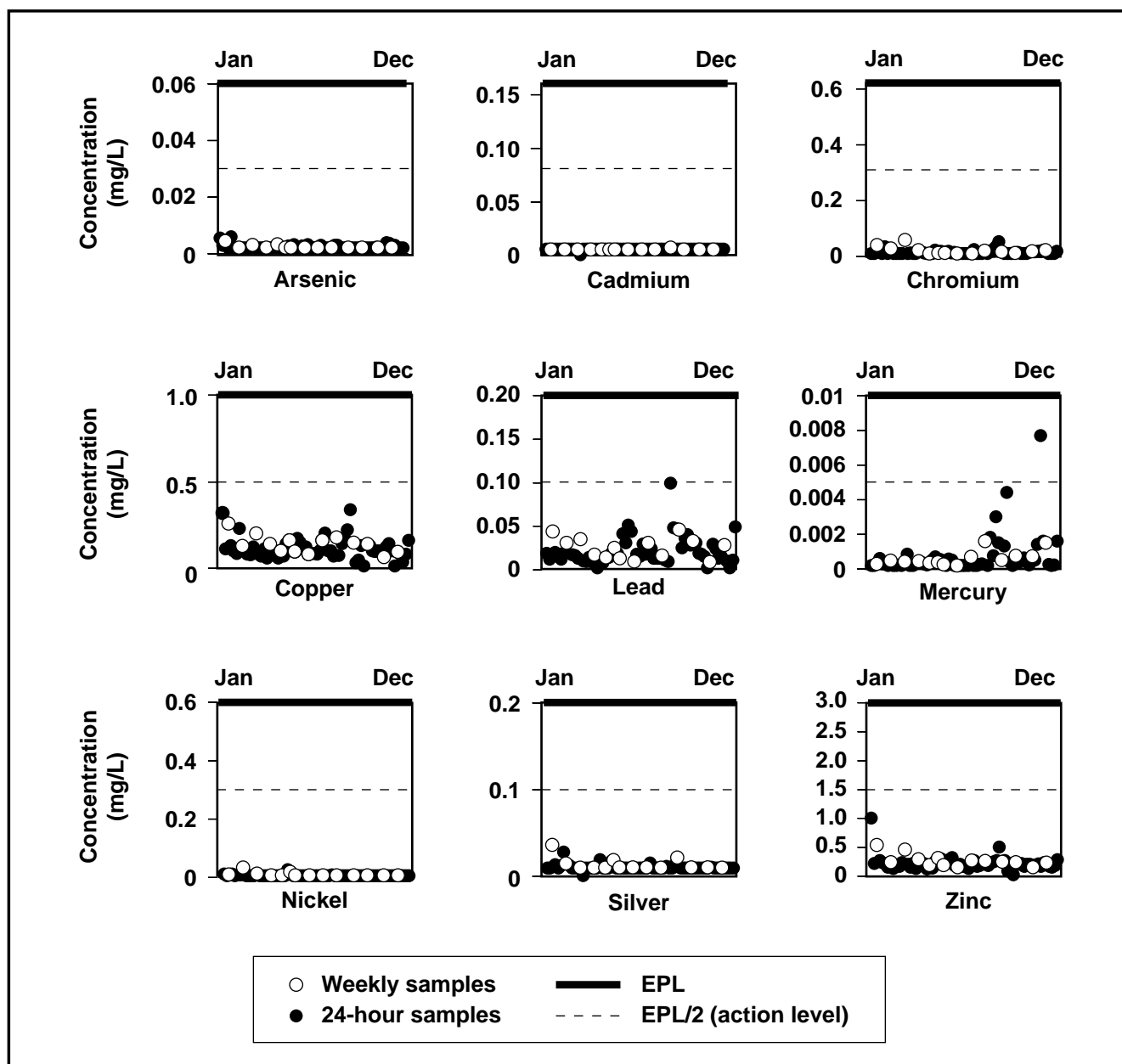


Figure 6-5. Concentrations of metals in 24-hour and weekly composite samples of LLNL sewage compared to effluent pollutant levels (EPLs) during 1996.

and the slightly elevated arsenic levels of 1993 continued in 1994. During 1995, the gas pad cleanup operations were reduced, and the slightly elevated arsenic levels were seen less frequently. In 1996, the gas pad operations were concluded, and arsenic levels returned to pre-1992 concentrations.



Table 6-10. Positively detected physical and chemical parameters in LLNL sanitary sewer effluent, 1996.

Positively detected parameter	Detection frequency ^(a)	Minimum	Maximum	Median	IQR ^(b)
24-hour composite sample parameters (mg/L)					
Oxygen demand					
Biochemical oxygen demand	12/12	23.8	274	190	137
Chemical oxygen demand	12/12	54	820	240	320
Solids					
Solid settling rate (mL/L/h)	12/12	5	43	22	7.5
Total dissolved solids	12/12	180	450	240	88
Total suspended solids	12/12	94	460	230	140
Volatile solids	12/12	60	380	87	130
Anions					
Chloride	12/12	36	63	51	11
Fluoride	9/9	0.082	0.9	0.13	0.08
Nitrate (as N)	1/12	<0.11	5	<0.5	—
Nitrate (as NO ₃)	2/12	<0.5	9.9	<0.5	—
Nitrite (as NO ₂)	1/12	<0.5	5	<2	—
Orthophosphate	8/9	4.4	210	11	11
Sulfate	12/12	17	4800	19	12
Alkalinity					
Bicarbonate alkalinity (as CaCO ₃)	12/12	130	240	200	15
Total alkalinity (as CaCO ₃)	12/12	130	240	200	15
Nutrients					
Ammonia nitrogen (as N)	11/12	<0.1	51	40	14
Total Kjeldahl nitrogen	12/12	30	50	43	9
Total organic carbon	11/11	4.2	8.4	45	19
Total metals^(c)					
Calcium	12/12	10	20	16	4.5
Magnesium	12/12	2.5	4.8	3.5	1.4
Potassium	12/12	17	68	19	2.3
Selenium	1/11	<0.002	<0.01	<0.002	—
Sodium	12/12	26	44	38	8



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Table 6-10. Positively detected physical and chemical parameters in LLNL sanitary sewer effluent, 1996 (concluded).

Positively detected parameter	Detection frequency ^(a)	Minimum	Maximum	Median	IQR ^(b)
Grab sample parameters					
Volatile organic compounds (µg/L)					
Acetone	12/12	55	1400	170	79
Chloroform	12/12	6.4	22	11	3.3
Methylene chloride	1/12	<1	160	<1	—
Toluene	1/12	<1	270	<1	—
Trichloroethene	1/12	<0.5	300	<0.5	—
Semivolatile organic compounds (µg/L)					
2-Methyl phenol	1/12	<5	21	<10	—
Benzoic acid	2/12	<25	<250	<50	—
Benzyl alcohol	6/12	<10	270	<37	—
Bis(2-ethylhexyl)phthalate	7/12	<5	34	12	11
Butylbenzylphthalate	1/12	<5	<20	<7.5	—
<i>m</i> - and <i>p</i> -Cresol	2/12	<5	<20	<10	—
Phenol	2/12	<5	<20	<9.1	—
Total recoverable phenolics (mg/L)	12/12	0.027	0.3	0.18	0.18
Total oil and grease (average, mg/L)	12/12	7.5	26	17	8.3

^a The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

^b Interquartile range. Where the detection frequency is less than or equal to 50%, the interquartile range is omitted.

^c The 24-hour composite sample results incorporated in **Table 6-7** are not represented in this section.

The monthly mercury values for the latter half of 1996 were higher than values reported for the previous two years. However, only one 1996 analytical result exceeded the action level in LLNL's Wastewater Discharge Permit, which states that archived daily composite samples must be analyzed for the pollutant of concern when the result for a weekly composite sample is 50% of, or greater than, the applicable effluent pollutant limit. This mercury analytical result (0.0077 mg/L), which exceeded the action level (0.005 mg/L), occurred in the latter half of 1996. The archived daily samples that corresponded to the appropriate weekly composite sampling period of November 26 through December 2 were submitted for mercury analysis. All of the analytical results for the daily samples were less than the effluent pollutant limit of 0.01 mg/L, with the



exception of the result for November 27. This analytical result of 0.013 mg/L exceeded the applicable effluent pollutant limitation, but LWRP, the regulatory agency, did not consider the value to be a violation of LLNL's Wastewater Discharge Permit because the mercury result fell within the range of uncertainty in the effluent pollutant limit.

All of the 1996 results for lead were well below the applicable action level and the applicable effluent pollutant limit, with the exception of the August 20 through 26 weekly composite sample. Even though the lead concentration for this sample (0.099 mg/L) was below the criterion for the action level, it was close enough that, as a best management practice, LLNL submitted the daily samples for lead analysis. All of the analytical results for these samples were less than the effluent pollutant limit. For 1996 as a whole, the monthly lead values presented in **Table 6-9** are comparable to results reported in previous years.

Seven inadvertent discharges were detected in 1996 by the continuous monitoring system (**Table 6-11**). These incidents did not represent a threat to the integrity of the operations at the LWRP. All of the incidents, which occurred during normal working hours on weekdays, involved either an acid or a base and were reported to the LWRP; LLNL is not permitted by the LWRP to discharge effluent with a pH below 5 or above 10. Five of the seven events were low pH incidents. Two of the seven events were above pH 10 but not considered enforceable exceedances of permit conditions because they did not exceed the duration criteria (40 CFR 401.17). (Uncontained pH releases of sufficient concentration and duration outside of the effluent pollutant limit range could disrupt treatment plant operations or cause the treated wastewater to exceed allowable concentration limits for discharge to the San Francisco Bay.) Only one incident was of sufficient concentration and duration to warrant a sewage diversion. For comparison, 1, 1, 0, and 13 such diversions occurred in 1995, 1994, 1993, and 1992, respectively. Subsequent analysis of the diverted effluent showed that the average pH was acceptable for release of the wastewater back to the sanitary sewer.

As a result of these incidents, the LWRP issued two letters of concern. The letters stated that the LWRP did not issue a notice of violation (NOV) for any of the incidents for reasons that included the availability of data for retention tank releases and the short duration and relatively small volumes of the incidents. However, in the second letter of concern, the LWRP indicated that continued similar pH incidents would result in an NOV. To eliminate the source(s) of these incidents, LLNL embarked on an educational campaign intended to supplement the existing administrative, engineering, and educational programs for promoting acceptable wastewater disposal practices. These efforts, completed in October 1996, included articles in the Laboratory's newspaper and electronic news bulletin and the distribution of an environmental alert to all employees through the LLNL mail system. The pH incidents, which began in January and occurred



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at least once every other month until September, did not occur again in the final three months of 1996.

Table 6-11. Inadvertent discharges detected by the continuous monitoring system in 1996.

Date	Contaminant	Estimated duration ^(a) (min)	Estimated volume ^(b) (L)	Minimum or maximum pH
1/31	Acid	3	4,300	3.5
3/22	Acid	4	3,300	2.4
5/17 ^(c)	Base	8	7,900	10.6
6/3 ^(c,d)	Base	30	35,000	10.8
8/12	Acid	2	2,100	2.4
8/26 ^(e)	Acid	2	2,400	2.8
9/11 ^(e)	Acid	3	4,900	3.5

^a The estimated duration includes only the time that the pH of LLNL effluent was outside of its permitted range.

^b The estimated volume includes only the volume of LLNL effluent that was outside of the permitted pH range.

^c LWRP did not consider these events as enforceable exceedances because they did not exceed the duration criteria.

^d This incident was of sufficient concentration and duration to warrant a sewer diversion; contained sewage was later returned to the sanitary sewer after analysis of the diverted effluent showed it had an acceptable pH. The event comprised a 30-minute excursion to pH 10.8, followed by a 15-minute fluctuation to pH 10.4, 25 minutes later. The volume of the second discharge was estimated to be 75,600 L (20,000 gal).

^e Based on a high sulfate concentration measured in an instantaneous sample acquired during the incident and the general usefulness of sulfuric acid in chemical work, the most probable cause for this incident is assumed to be sulfuric acid.